GRAVITATIONAL WAVE ASTRONOMY AND ITS POTENTIAL FOR NEW DISCOVERIES

A RESEARCH PAPER SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE

MASTER OF ARTS

BY

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DESEMBER 2017

ACKNOWLEDGEMENTS

First, I would like to thank my advisor Dr. Eric Hedin. He helped me to complete my research paper, and he gave me a lot of advice. Dr. Hedin is very respectful, and he is a great professor. Second, I want to thank my parents for the unceasing encouragement, support, and attention. I love them as the size of the sky. Also, I would like to thank the Department Chairperson Dr. Joel Bryan because he helped me when I had any problems or questions. Finally, I would like to thank all of my family for their support.

Thank you,

Introduction

Gravitational waves are the ripples in the curvature of space-time that travel outward from the source that made them. It is a concept predicted by Einstein's theory of general relativity. The theory states that a mass tends to distort both space and time in the same way a heavy bowling ball would distort a trampoline. Whenever an object is accelerated, it generates ripples in space-time similar to a boat that causes ripples in a pond. It is similar to how an accelerated electrical charge creates an electromagnetic wave. The space-time ripples are referred to as gravitational waves. The waves are weak and difficult to direct, and missions such as LISA and LIGO hope to identify gravitational waves by detecting slight alterations in the distances between objects at predetermined distances. In this research paper, gravitational waves will be addressed under various subtopics covering the physics of gravitational waves, their origin, gravitational wave detection, LIGO, LISA, and gravitational wave astronomy.

Gravitational waves refer to propagating fluctuations of gravitational fields that represent a series of ripples occurring in space that are generated by massive bodies undergoing acceleration (Kostas, 2002). These waves were theoretically discovered by Albert Einstein. According to Einstein, gravitational waves are created during events such as super massive black hole mergers or collisions that occur between two galactic-center black holes that are thought to be as much as two billion times more massive than the sun. Resulting collisions are very powerful and they create distortions in space that are referred to as gravitational waves. Other sources of gravitational waves include distant systems such as smaller stellar mass black holes and Extreme Mass Ratio Inspirals (EMRIs) that come form black holes that orbit super massive black holes. Through studying gravitational waves, observations and theoretical research will enhance our understanding of different astronomical systems, which include binary neutron stars, cataclysmic variables, young neutron stars, low mass x-ray binaries, and the anisotropy of microwave background radiation. Gravitational radiation is therefore expected to be highly important as a new astronomical research field. Expected causes of gravitational waves include novel emissions of gravitational waves as a result of bulk motions of sources of individual atoms or electrons. Gravitational waves are expected to complement electromagnetic waves in astronomical research, in that they carry a different type of information concerning their sources.

New expectations of gravitational wave research include studies of the polarization of waves from the orbit of binary systems. This analysis could discover new relationships that exist in binary system, such as the inclination of their orbit to the line of sight. Gravitational waves are one of the frontline scientific discoveries applied to effective and efficient confirmation of a black hole's existence and properties. The radiation emitted as gravitational waves can be observed using the Laser Interferometer Gravitational Wave Observatory (LIGO) and (in the future) the Laser Interferometer Space Antenna (LISA) technology (Abbott et al., 2017). Gravitational waves that interact with matter can be utilized to enhance our understanding of hidden regions, which includes the interior of supernova explosions, or the big bang. This paper also focuses on the growth and development of detectors and their sensitivity, both on the ground and in space. The areas involved in the research study include reviewing various sources of gravitational sources and important roles played in observation through first and second generation interferometers. The research analyzes astrophysical information that comes from various observations.

Physics of gravitational waves

Gravitational waves are the ripples in space-time caused by some of the most violent and energetic processes in the universe. Einstein applied the theory of relativity to predict the existence of gravitational waves. His computations showed that huge accelerating objects would cause a disruption in the space-time in such a way that waves of the distorted space would radiate from the source. The ripples would travel at the speed of light, traversing the universe and carrying with them information on the cataclysmic origins and clues to the nature of gravity. Catastrophic events like colliding black holes, the collapse of stellar cores, coalescing neutron stars, and the slight wobbly rotation of neutron stars generate the strongest gravitational waves. Gravitational waves were predicted in 1916, but proof of their existence was in 1974 (Sathyaprakash & Schutz, 2009). Two astronomers discovered a binary pulsar which was composed of two dense, heavy stars in orbit around each other. It was a system that would generate gravitational waves and was used to test Einstein's prediction. The astronomers measured how the period of stars' orbits changed over time, and after years of observations, it was established that the stars were getting closer to each other at a rate predicted by general relativity. The system has been observed for more than 40 years, and it is clear that it is emitting gravitational waves. Many astronomers have researched on the timing of the pulsar radio emissions and identified similar effects, thereby confirming the existence of gravitation waves. The confirmations are indirect, however, and not through actual detection of the waves.

In 2015, LIGO sensed physical distortions in spacetime caused by passing gravitational waves produced by two colliding black holes very far away. The distant origins of gravitational waves can be violent, but they reach the surface of the Earth as small and less disruptive disturbances of spacetime (Sathyaprakash & Schutz, 2009).

Origin of gravitation waves

Objects with a mass that accelerates generate gravitational waves, which includes humans, cars, and airplanes. However, most of the gravitational waves made on earth are too small to detect. It is not possible to have detectable gravitation waves from earth, hence it is necessary to study them where they are generated by nature. The universe has massive objects that undergo rapid accelerations such as black holes, neutron stars, and stars. The objects produce various types of gravitational waves, and each has a unique characteristic vibration signature that can be sensed by interferometers. The various types are continuous gravitational waves, compact binary inspiral gravitational waves, stochastic gravitational waves, and burst gravitational waves.

A single spinning massive object that generates continuous gravitational waves is called a neutron star. Any imperfections in the spherical shape of the star are likely to generate gravitational waves in the process of the star's spin. The gravitational wave produced by a star with a constant spin rate is continuous in the sense of having constant frequency and amplitude, and hence termed as a continuous gravitational wave. Orbiting pairs of the massive objects such as the white dwarf stars, black holes, and neutron stars generate compact binary inspiral gravitational waves. Compact binary systems exists in three categories; binary neutron star, binary black hole, and neutron star-black hole binary. The mechanism of producing the waves is similar for the three categories (Plan, 2010). Inspiral occurs over millennia as the pairs of dense, compact objects revolve around each other. They generate gravitational waves that remove some energy of the orbit. As they revolve and lose energy, they get closer and closer together and that makes them orbit faster than before thereby emitting more and stronger gravitational waves. They lose more orbital energy as they get closer to each other, orbit faster and lose even more energy as they move closer to each other in a spiraling embrace. They continue emitting gravitational waves and orbit closer and closer and eventually collide, leading to a cataclysmic event. LIGO astronomers detected the gravitational waves and identified that the gravitational waves were produced during the final stages of the merger of two black holes (ibid, 2010).

Stochastic gravitational waves are formed by the many small gravitational waves from every direction over the universe. Stochastic means random pattern and the waves generated are the smallest and most difficult to detect. A part of the stochastic signal originates from the Big Bang, and the detection of the relic gravitational waves from the Big Bang would allow the visualization of the history of the universe (Abbott, et al., 2007).

Burst Gravitational waves have never been detected directly before, and there are uncertainties about such waves. There is limited information on the physics of the system to predict gravitational waves, and there is an expectation of finding the waves from systems that have not been known before. In searching for gravitational waves, there cannot be an assumption that they will have well-defined properties similar to those of the continuous and compact binary inspiral signals do. For burst gravitational waves, scientists should maintain the ability to recognize any noticeable pattern of signals, since they have not been detected before.

Gravitational wave detection

In 2015 September, LIGO made the first direct observation of the gravitational waves, which are the ripples found in space and time as predicted by Einstein many years ago. For the first time, scientists observed the ripples in spacetime that confirmed the earlier prediction. Gravitational waves carry the information about their dramatic origins and the nature of gravity. According to physicists' findings, the detected gravitational waves are generated in the last fraction of a second of the collision of two black holes to form a single, huge spinning black hole. The collision had been predicted previously, but no one had ever observed it. Gravitational waves were detected first on September 14, 2015, by the twin Laser Interferometer Gravitational-wave Observatory (LIGO) detectors located in U.S.A. See Fig.1 for a schematic of the LIGO interferometer. By the observed and recorded signals, LIGO scientists estimated that the black holes were approximately 29 and 36 times to the mass of the sun. Approximately 3 times the mass of the sun was transformed into gravitational waves within a fraction of a second, having a power output of about 50 times the entire visible universe. The differences in the recording times for the detectors located in different places shows the likelihood of the source to be in the Southern Hemisphere (Abbott, et al., 2009).

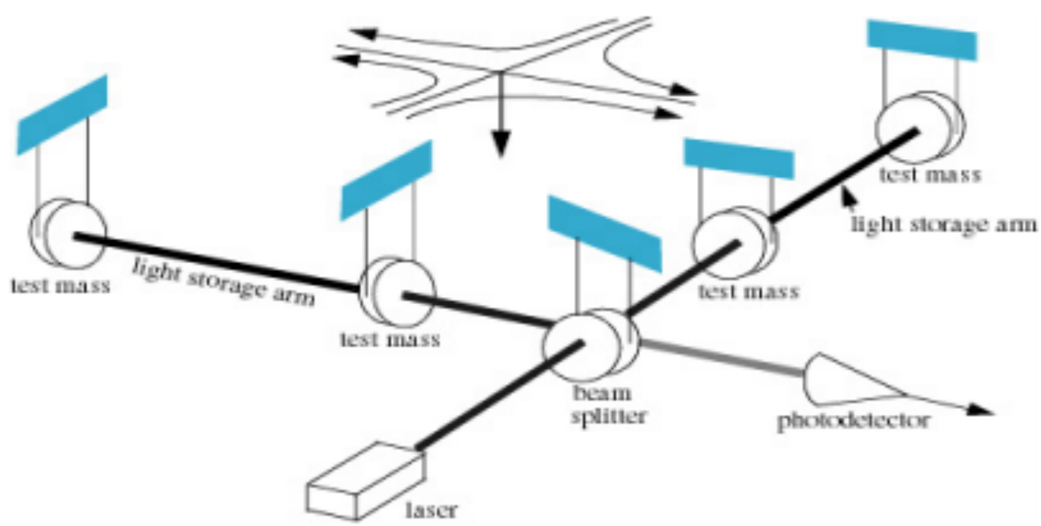

Figure 1: LIGO project

"A schematic of the laser interferometer and detectors used in the LIGO project"

Retrieved from: https://labcit.ligo.caltech.edu/~ajw/ligo_public.pdf

General relativity explains that a pair of black holes going around each other tends to lose energy by emitting gravitational waves. It makes them slowly approach each other over billions of years and very fast in the last few minutes. In the final fraction of a second, two black holes collide into each other at top speed (0.5c for GW150914) and form one massive black hole. The process converts a fraction of the combined black holes' mass into energy. The use of Einstein's formula: $E=mc^2$ helps to estimate the magnitude of energy which is emitted as a burst of gravitational waves. LIGO observed the gravitational waves and detected them as earlier described.

The LIGO discovery is termed as the first observation of gravitational waves that was made by the measurement of the small disturbances made by waves in space and time as they pass by the earth. The observation of gravitational waves meets the goal of Einstein's legacy of the general theory of relativity. The discovery was advanced by the enhanced capabilities of LIGO, which were an upgrade that increased the sensitivity of the tools compared to the initially discovered LIGO detectors. It allowed an increase in the magnitude of the universe probed and the discovery of gravitational waves occurred in the first attempt after the upgrade. LIGO research is conducted by a scientific collaboration of more than 1000 scientists who assisted in developing the detector technology and analysis of data. The detector is comprised of LIGO interferometers and GEO60 detectors. The detection capability is the new breakthrough making the field of gravitational wave astronomy a reality. LIGO was first introduced as a method for detecting gravitational waves in the 1980s. Its description is similar to that of Einstein theory of general relativity that was written 100 years ago. The discovery helps the exploration of the other side of the universe revealing objects and phenomena made from warped spacetime, such as colliding black holes and gravitational waves.

The advanced LIGO detectors are a major contribution to science and technology. For each observation, the 4-km long L-shaped LIGO interferometer uses laser light split into two beams traveling back and forth within the arms. The distance between mirrors is monitored by beams placed at the end of the arms. Based on Einstein's theory, the distance between mirrors changes by a very small amount when a gravitational wave passes by the detector. A change in the length of the arms equal to one thousandth the diameter of a proton is detectable using the instrument. Laser and suspension technology helped to develop the GEO 600 detector and its application in making Advanced LIGO the most complex and sensitive gravitational wave detector.

Laser Interferometer Gravitational-wave Observatory (LIGO)

LIGO was developed to detect the cosmic gravitational waves and also to develop gravitational-wave observations similar to other astronomical tools. The laser interferometer gravitational wave observatory (LIGO) is an instrument dedicated to detection of the cosmic gravitational waves and also the measurement of waves for use in scientific discovery. It has two separated installations in U.S.A but operates as a single observatory. The technique used in the detection of gravitational waves is laser interferometry. The previously developed LIGO observatories were made and operated by Caltech and MIT, but they never detected any gravitational waves. An upgrade to the LIGO project for enhancing the properties of LIGO detectors started in 2008 and began its operation in 2015. The LIGO Scientific Collaboration (LSC) reported the detection of gravitational waves in 2016. Gravitational waves provide a great opportunity to perceive the universe in a new perspective and provides insights that were not previously known. The LIGO detectors that existed initially completed observations beyond the original design of sensitivity and the data has been interpreted to develop the upper limits on the gravitational wave flux. The advanced LIGO project upgraded the existing gravitational wave interferometers and made the instruments more sensitive, making gravitational wave detections a nearly routine occurrence.

In the history of humans, the cosmos has been observed in a manner involving bare eyes and telescopes that helped us to learn by viewing various parts of the electromagnetic spectrum such as infrared light, x-rays, gamma rays, and radio waves. The information allows us to only learn about 10% of the components of the universe using the conventional methods of observation. LIGO was designed to sense the presence of waves from dark and distant masses. The instrument achieves this by detecting gravitational waves, which are ripples in the force of gravity and generated from violent occurrences such as the collision of stars and vibrations of black holes.

The operation of the Advanced LIGO experiment is not as complex as one would think. The primary interferometer has two beamlines having 4 km in length that creates a power-recycled Michelson interferometer with Gires-Tournois etalon arms. A stabilized laser emits a beam having a power of 20 W and passes through a power recycling mirror. The mirror transmits light incident from the laser and reflects light, thereby increasing the power of light field between the mirror and the other beam to 700 W. The light then travels along two arms (placed at 90 degrees) where the path length is monitored (Althouse & Zucker, 1992).

Upon the passage of a gravitational wave through the interferometer, the space-time in the local area is changed. By the source of the wave and its polarization, there is a change in length of one or both cavities between the arms that cause light in the cavity to be slightly out of phase with the incoming light. The cavity gets out of coherence, and the beams have a very slight periodically varying detuning, thereby resulting in a measurable signal. After making several trips down the 4 km length to the mirrors back and forth, the two separate beams exit the arms and join at the beam splitter. The beams are kept out of phase such that when the arms are both undisturbed, the interference of their light waves subtract and no light arrives at the photodiode. Upon the passage of gravitational waves through the interferometer, the distances along the arms are shortened and lengthened, thereby causing the beams to be slightly out of anti-phase. The beams come in phase and create resonance where some light reaches the photodiode, thereby indicating a signal. The light without a signal is returned to the interferometer by the use of power recycling mirror, which increases the power of light in the arms (Althouse & Zucker, 1992).

Gravitational wave GW150914 and its detection by Advanced LIGO

The experiments to detect gravitational waves started with Weber using his resonant mass detectors in the 1960s, followed by cryogenic resonant detectors. Interferometric detectors came into public limelight in the 1960s and '70s (Abbott, et al., 2016). The study of noise and performance of the detectors led to their improvement using long-baseline broadband laser interferometers with a likelihood of increased sensitivity. In 2015, the LIGO Hanford observatories detected the coincidental signal GW150914. The initial detection was achieved using low-latency search of generic gravitational-wave transients and was reported within three minutes of acquiring data. The matched-filter analyses using relativistic models of compact binary waveforms recovered GW150914 as the major event from each of the detectors as reported. It occurred with 10-msec intersite propagation time and had a combined signal-to-noise ratio of 24. Only LIGO detectors were observing at the time of GW150914. The Virgo detector was undergoing an upgrade as was the CEO 600, but it was not sensitive enough to detect the event. By the use of only two detectors, the source position was determined by the relative arrival time and was localized to approximately 600 deg^2 (Abbott, et al., 2016).

The main features of GW150914 date back to being produced by the coalescence of two black holes. Within 0.2s, the signal increased in frequency as well as amplitude in approximately eight cycles from 35 Hz to 150 Hz where the amplitude reached its maximum. The most relevant explanation for the signal is the inspiral of two orbiting masses, m_1 and m_2 as a result of gravitational-wave emission. At lower frequencies, the evolving signal has the characteristics of the chirp mass, as shown below,

$$\mathcal{M} = \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{1/5}} = \frac{c^3}{G}\left[\frac{5}{96}\pi^{-8/3} f^{-11/3}\dot{f}\right]^{3/5},$$

where f is the observed frequency, f(dot) its time derivative, G and c, are the gravitational constant and speed of light. The total mass is equal to $m_1 + m_2$ in the detector frame. To have an orbital frequency of 75 Hz, the objects ought to be very close and compact. The equivalent Newtonian masses orbiting at such a frequency would only be approximately 350 km apart. A pair of neutron stars impacting would not have the required mass, and the deduced chirp mass would be a large total mass and merge at a lower frequency. This leaves black holes as the only objects that can reach a frequency of 75 Hz without any contact. We present a general-relativistic analysis of GW150914, and Fig. 2 shows the calculated waveform using the resulting wave (Abbott, et al., 2016).

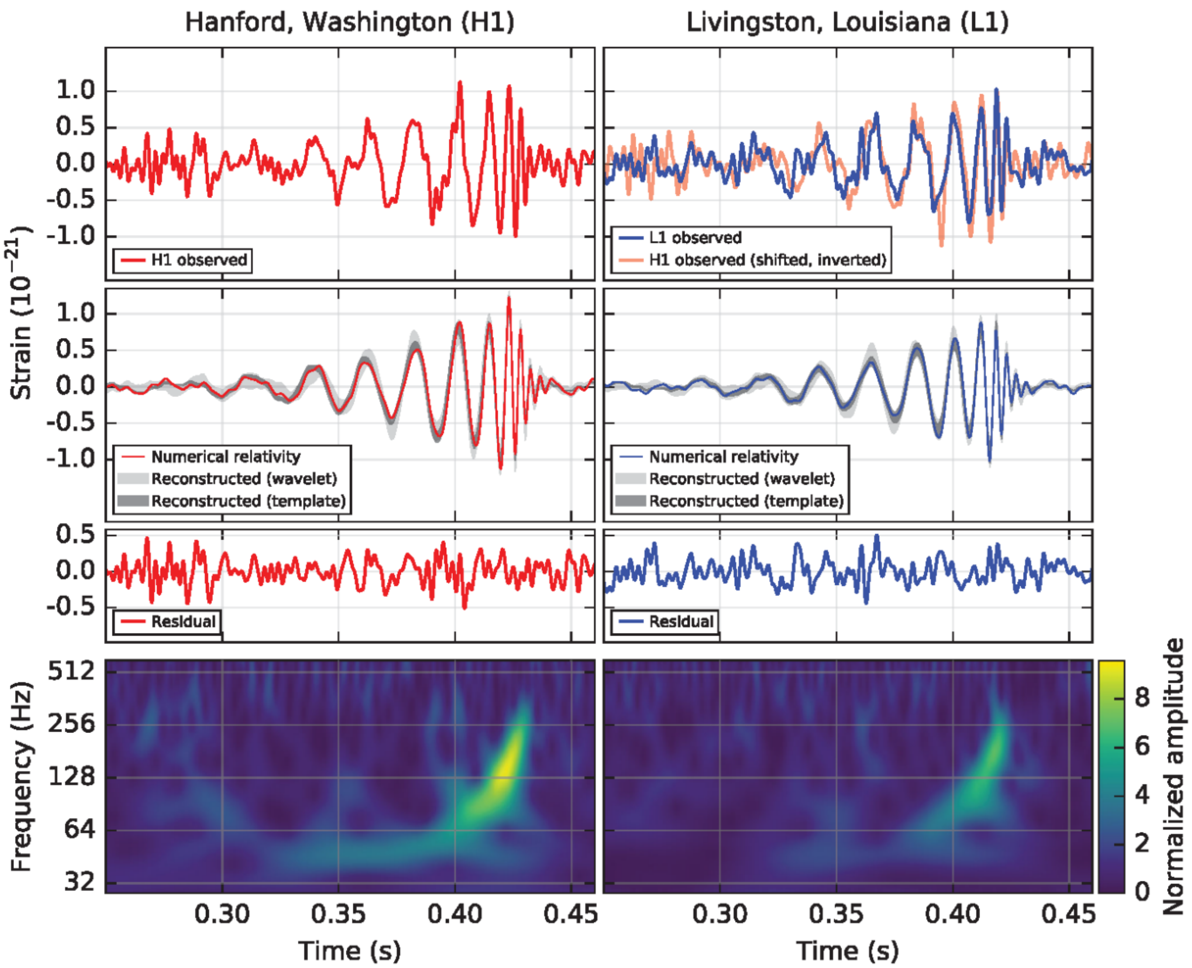

Fig.2: “The Gravitational-wave event GW150914 observed by the LIGO Hanford and Livingston detectors. Top row, left: H1 strain. Top row, right: L1 strain. GW150914 arrived first at L1 and later at H1; for a visual comparison, the H1 data are also shown, shifted in time by this amount and inverted (to account for the detectors’ relative orientations). Second row: Gravitational-wave strain projected onto each detector in the 35–350 Hz band. Third row: Residuals after subtracting the filtered numerical relativity waveform from the filtered detector time series. Bottom row: A time-frequency representation of the strain data, showing the signal frequency increasing over time” Source: (Abbott, et al., 2016).

Gravitational wave astronomy uses multiple and widely separated detectors to differentiate the gravitational waves from the local instrumental and environmental noise, provide source sky localization, and measure the wave polarizations. LIGO sites operate a single Advanced LIGO detector which is a modified Michelson interferometer used to measure the gravitational-wave strain as the difference in length of its orthogonal arms (Eberle, et al., 2010). For sufficient sensitivity in measuring gravitational waves, the detectors have several enhancements to Michelson interferometer. The interferometry techniques help to maximize the conversion of strain to the optical signal and minimize the effect of photon shot noise. Various systems are used to provide more than ten orders of magnitude isolation from the ground motion for the frequencies above 10 Hz. The use of low-mechanical-loss materials in the test masses, as well as their suspensions, helps to minimize thermal noise. For minimization of the additional noise sources, all the components other than laser sources are fixed on vibration isolation stages in a vacuum. The detector response to the gravitational waves is tested using an injected simulated waveform from the calibration laser. For the monitoring of environmental disturbances and their influence on the detectors, each observatory site has various sensors including seismometers, accelerometers, microphones, magnetometers, radio receivers, weather sensors, power line monitors, and cosmic-ray detector (Billings, 2016).

Interpretation of GW150914

GW150914 shows the existence of huge mass black holes that are more massive than ≃25M (M is the mass of the sun). It also demonstrates that binary black holes can form in nature and combine within a long time. The binary black holes have been predicted to form in isolated binaries as well as dense environments by dynamical interactions. The formation of the massive black holes requires weak massive star winds that are tenable in stellar environments. The observed results constrain the rate of stellar-mass binary black hole mergers in the universe. By the use of the various models of underlying binary black hole mass distribution, rate estimates are obtained ranging from 2–400 Gpc^{-3} yr^{-1} in the co-moving frame. It aligns with the range of rate predictions as shown. The predictions for a stochastic background of gravitational waves show that, if signals from the population were detected, it would have information on the evolution of such binary systems throughout the history of the universe. GW150914 was detected using two different types of searches. One focuses on recovering signals from the objects using optimal matched filtering with waveforms having general relativity predictions. The next search focuses on a broad range of generic signals with minimal assumptions about the waveforms. Each of the searches identifies the events detected at both observatories and are consistent with the inter-site propagation time.

Other gravitational wave observations coming online shortly

More than 100 years ago, Albert Einstein predicted the existence of gravitational waves, and in 2015, scientists proved him right in some aspects. The scientists have big plans for more detectors and observatories in future. An example is Virgo, which is an upgraded version of the experiment similar to LIGO experiments that give scientists the ability to identify where gravitational waves are located in the sky (Harry & LIGO Scientific Collaboration, 2010). The detector helps astronomers learn more about what happens in the universe with more details than before. In future, LIGO will record more than the sounds of the newly merged black holes. The current observatories could also help to identify spinning neutron stars' mass-distribution and their star quake-shaken interiors that could pop up their surfaces. The ultimate goal for scientists is to see whatever makes the waves and also study it. Wave information in the two LIGO detectors as well as the time delay gives scientists hundreds of square degrees' view of the sky, but not a specific location. Thus, the addition of the Virgo detector helps to associate the gravitational waves with the points that cover only tens of square degrees in the sky (Courier, 2017).

Gravitational wave astronomy

Gravitational wave astronomy is a developing field of observational waves that aims at using gravitational waves in collecting observational data about the objects such as neutron stars and black holes. The ordinary gravitational wave frequencies are low and challenging to detect, and their amplitudes are small, but the higher frequencies occur in more dramatic occurrences and thus became the first to be observed. Astronomy has traditionally relied on electromagnetic radiation that has by observing various parts of the electromagnetic spectrum. The detection of gravitational waves has led to a new understanding of the universe as advanced by gravitational wave astronomy (Buonanno, 2017).

Expectations for discoveries in the field of gravitational wave astronomy

Scientific knowledge about gravitational waves is expected to play several important roles in the modeling of new observations in astrophysical systems. The current nature of gravitational waves is based on gravitational radiation theory, which is relativistic astrophysics. The technology of astrophysics intends to apply gravitational wave detectors, such as interferometers, to continually monitor for the collision of black holes (Lee, 2016). The spacetime disturbances generated by the waves are determined by laser beams traveling along arms of an interferometer to end mirrors. Through interference of the waves at a beam splitter, the phase relationship between the beams can be defined. Gravitation wave characteristics are analyzed while the beams through which the wave is passing stretch and compress. Minute movement of the interferometer arms changes their lengths with time, becoming large and smaller in size. Stretching and squeezing due to the waves defines how gravitational wave detectors can be modified to produce best results (Lee, 2016).

Depending on the need and energy-level requirements in the future, new detectors will be developed to search for gravitational waves to understand how gravitational impacts can reveal new information about astronomical events. Tremendous scientific and technological advances will be developed to support existing gravitational wave detector systems in Livingston, Louisiana, and Hanford, Washington, USA (Schutz, 1999). Support equipment that is intended to play a role in understanding the impact of gravitational waves includes lasers and optics, high vacuum systems, high-performance computers, and servo control systems (Schutz, 1999). The modern Laser Interferometer Gravitational Wave Observatory (LIGO) first identified two binary black hole coalescence signals that were characterized by high statistical significance (Abbott et al., 2017). Newly discovered advancements have led to the launching of a new trend in science involving observational gravitational wave astronomy. Scientists are focusing on finding out alternative measures that they can implement and use to further investigate discoveries in binary black holes. They also purpose using general relativity theory to improve previous limitations on accessing new binary black holes (Abbott et al., 2017).

New binary systems continuously produce dynamic regimes of strong fields of gravity. Discoveries will be based on detecting velocities as well as their relative location in space and the time spent travelling through space. Discoveries concerning gravitational waves are associated with several implications. Enhanced acquisition of gravitational wave signals using new ways and methods provides unique information about energetic astrophysical events.

Discoveries realized include bringing new and incomparable insight in understanding of gravitational effects related to matter, space, and time.

Strategies for New Discoveries in Gravitational Waves

Future discoveries will include detection of gravitational waves produced through massive stars burning nuclear fuels. Such process involves inducing violent gravitational explosions in the production of energetic events such as supernovae (Abbott et al., 2017). Analysis of such gravitational waves are intended to inform ideas on how stars can produce such explosions.

Scientific growth and development strategies for discovering scientifically beneficial gravitational wave information include the development of a global ground based network that aims at building sophisticated gravitational wave detectors for constant searching of the sky (Kostas, 2002). New detectors from Italy, Japan, and India are under construction for further discoveries of different wavelengths of gravitational waves. Europe on scientists are also busy in developing the Einstein Telescope, intended to have strong observing power of over ten times the sensitivity in comparison to current detectors. The technology enables visualizing gravitational waves at the edges of the universe. Researchers are also working with other types of detectors that can capture long wavelength gravitational waves. Tools also used include radio telescopes (Kostas, 2002).

Recent plans for developing the Laser Interferometer Space Antenna (LISA) detectors are being debated. LISA technology is capable of detecting intermediate-mass black hole collisions, as well as providing phase transitions (Karsten, 2016). LISA will be integrated with ultrasensitive infrared detectors. Such improved tools will facilitate accurate and precise measurement of the polarization of cosmic gravitational waves. The sensors will have the power to detect faint whispers of gravitational waves produced by effects of the Big Bang. LIGO technology is also opening new methods and potential in discovering cosmic waves (Abbott et al., 2017). LIGO and LISA technology is in the process of being utilized effectively to ensure that scientists completely understand additional issues concerning the universe. The future is revealing the strong potential for developing different tools for discovering the universe. Future tools will solve problems associated with previously hidden regimes that go beyond black holes, including the big bang, among others (Abbott et al., 2017).

LISA (Laser Interferometer Space Antenna) and its potential for discoveries

LISA is one of the technologies focusing on accomplishing the goal of knowing about the beginning, evolution, and structure of the universe. LISA has a high potential for exploring the astrophysical universe as well as different laws of nature. LISA technology has a potential of determining low frequencies in the milli-Hertz range (Tyler, 2016). The most suitable technological tool for determining gravitational waves through measuring their frequency is LISA. It enhances measuring a large broad band that has low frequencies. It is designed with long arms specified for allowing passage of waves. It has well-integrated systems with the primary impetus for efficient and effective detecting of slight waves. LISA has special attributes such as an arm's length of 1 million km. It has similar capabilities such as that of Michelson interferometer (Tyler, 2016). Its arm is fully equipped for the special purpose of observing minute sources of gravitational waves. LISA is capable of resolving differences that were revealed by earlier systems. It has the capability of ensuring traditional astronomical systems are fully integrated with the electromagnetic spectrum. It has the clear advantage of observing visible light, viewing infrared rays as well as identifying x-rays (Karsten, 2016). LISA has capabilities of opening gravitational waves windows in various spaces. It will ensure complete measurement of gravitational radiation, at the longer length of broadband of frequencies from 0.1 MHz to 100 MHz.

European Space Agencies are focusing on developing and constructing Laser Interferometer Space Antenna (LISA) having modern modifications and high-level standards for effectiveness and efficiency of detecting gravitational waves (Tyler, 2016). "The three satellites are separated by a distance of 1 Mio km" (Karsten, 2016). A modification of the arms will include three arms each having 5 million km in length. LISA satellites will be positioned to form a triangular interferometer (Karsten, 2016). The design is capable of ensuring that it can sense any gravitational wave emitted by any merging or supermassive black holes. The systems will have the capability of determining gravitational waves since the first stars began shining in the world after the big bang.

Another project is eLISA which is an evolving technology design aiming at implementing LISA Pathfinder and LISA precursor (Karsten, 2016). The new project has eliminated bulky space craft. An alternative space-based interferometer is designed with new technology that integrates microscopic cloud of atoms. Such strategies are facilitating economic projects that reduce needs for long and expensive baselines. LISA technology will enhance scientists' view of the biggest and most violent events in the universe. It has a payload of two Gold platinum cubes that have the possibility of coming as close as possible to a weightless state, thus resulting in a condition of rest (Karsten, 2016). It has shielded vacuum enclosed within the spacecraft and this design modification ensure that the cubes can only sense gravitational waves.

Various improvements suggested in the new technology of LISA include having arms as long as possible, such as tens of millions of kilometers, that are linked using laser systems (Karsten, 2016). Such modifications guarantee that LISA can detect small distance changes caused by influence of passing gravitational waves. The proposed future studies are focusing on implementing perfectly stationary sensors with LISA technology with capability of resting within sunlight-baked spacecraft (Karsten, 2016). The proposed technology requires sophisticated systems such as heaters, antennas and thrusters. However, implementing such a detector is highly expensive and requires bulk spacecraft. The high cost of implementing such technology makes efforts to design such a system difficult to achieve.

Conclusion

Gravitational waves were initially inferred indirectly by observing two pulsars and noticing them slowing down due to the loss of energy from emitting the gravitational waves. The direct detection of waves is essential in providing information about the early universe. Cosmic microwave background radiation provides details of the universe years after the onset of the universe. Some patterns in the cosmic microwave background can be measured in the large-scale structure of the universe as caused by tiny random perturbations since the universe expanded rapidly. Various aspects of gravitational waves have been discussed in this research, including the origin, detection, and the breakthroughs by Laser Interferometer Gravitational-wave Observatory (LIGO). The future of gravitational wave observations is bright with the continued research and development of detectors alongside the LIGO detectors.

Gravitational waves travels at the speed of light. They can be detected by devices such as the Laser Interferometer Gravitational Wave Observatory (LIGO) and the Laser Interferometer

Space Antenna (LISA) technology. Various gravitational wave detectors are focusing on discovering interesting activities happening in the universe. LIGO and LISA are configured to indentify the waves by measuring changes induced in the lengths of the interferometer arms by passing gravitational waves. LISA technologies can be referred to as next generation detectors. They are characterized by having more than ten times sensitivity power compared to previous sensors. Taking into consideration the overall progress on the development of different sophisticated systems to study the universe it is clear that desired dreams of scientists of reaching a state of perfect isolation from noise vibrations will be possible. There is still much work to do, and more research work is required to reach the goal of perfection in gravitational wave astronomy.

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